4-1-2017

Dental workforce availability and dental services utilization in Appalachia: a geospatial analysis

Xue Feng
West Virginia University

Usha Sambamoorthi
West Virginia University

R. Constance Wiener
West Virginia University

HHS Public Access
Author manuscript
Community Dent Oral Epidemiol. Author manuscript; available in PMC 2018 April 01.

Published in final edited form as:
Community Dent Oral Epidemiol. 2017 April ; 45(2): 145–152. doi:10.1111/cdoe.12270.

Dental Workforce Availability and Dental Services Utilization in Appalachia: A Geospatial Analysis

Xue Feng, MPH[1,*]
[1]Department of Pharmaceutical Systems and Policy, School of Pharmacy, West Virginia University, Morgantown, 26505, WV, USA

Usha Sambamoorthi, PhD[1]
[1]Department of Pharmaceutical Systems and Policy, School of Pharmacy, West Virginia University, Morgantown, 26505, WV, USA; usambamoorthi@hsc.wvu.edu

R. Constance Wiener, DMD, PhD[2]
[2]Department of Dental Practice and Rural Health, School of Dentistry; West Virginia University, Morgantown, 26505, WV, USA; rwiener2@hsc.wvu.edu

Abstract

Objectives—There is considerable variation in dental services utilization across Appalachian counties, and a plausible explanation is that individuals in some geographical areas do not utilize dental care due to dental workforce shortage. We conducted an ecological study on dental workforce availability and dental services utilization in Appalachia.

Methods—We derived county-level (n = 364) data on demographic, socio-economic characteristics and dental services utilization in Appalachia from the 2010 Behavioral Risk Factor Surveillance System (BRFSS) using person-level data. We obtained county-level dental workforce availability and physician-to-population ratio estimates from Area Health Resource File, and linked them to the county-level BRFSS data. The dependent variable was the proportion using dental services within the last year in each county (ranging from 16.6% to 91.0%). We described the association between dental workforce availability and dental services utilization using ordinary least squares regression and spatial regression techniques. Spatial analyses consisted of bivariate Local Indicators of Spatial Association (LISA) and geographically weighted regression (GWR).

Results—Bivariate LISA showed that counties in the central and southern Appalachian regions had significant ($p < .05$) low-low spatial clusters (low dental workforce availability, low percent dental services utilization). GWR revealed considerable local variations in the association between dental utilization and dental workforce availability. In the multivariate GWR models, 8.5% (t-statistics >1.96) and 13.45% (t-statistics >1.96) of counties showed positive and statistically significant relationships between the dental services utilization and workforce availability of dentists and dental hygienists, respectively.

*Corresponding author xufeng@mix.wvu.edu.

Competing interests
There are no competing interests.

Conclusions—Dental workforce availability was associated with dental services utilization in the Appalachian region; however, this association was not statistically significant in all counties. The findings suggest that program and policy efforts to improve dental services utilization need to focus on factors other than increasing the dental workforce availability for many counties in Appalachia.

Keywords

dental workforce availability; dental service utilization; Appalachia; geographical disparity

Introduction

Poor dental health is very common in the Appalachian region,[1] which consists of 421 counties in 13 states from New York to Mississippi.[2] Specifically, caries-related tooth loss is more likely in this region than other regions of the US.[3] Poor dental health is influenced by many factors (in addition to those associated with the oral biofilm), such as sex and socioeconomic status.[4, 5] Regular dental visits are important for good oral health.[6,7] Variations in dental services utilization *within and between* Appalachian counties have been reported,[8] and some of the observed variation may be attributed to differences in the distribution of the dental workforce availability.

In the rural areas of the US, there is evidence that low dental services utilization is due to lack of dental workforce availability.[9, 10] Allison et al. reported that in rural Kansas, residents of counties with a higher number of full-time equivalent (FTE) dentists per 100,000 population were more likely to use dental services within the last year (Adjusted Odds Ratio = 1.01, $p < .01$) than residents living in counties with a lower concentration of dentists.[10] Some regions of the US have severe dental workforce shortage. Particularly, in some Appalachian counties there is only one practicing dentist. This is the case in Monroe, Gilmer, and Calhoun counties in West Virginia.[11] Dental service utilization may vary across counties as dentist availability and dentists-to-population ratios differ across counties.

It is important to understand the extent to which county-level variations in dental services utilization are influenced by the dental workforce shortage and demographic and socio-economic characteristics such as sex, age, race, and poverty. Geo-mapping and spatial analyses, including *Local indicators of spatial association (LISA)* and *geographically weighted regression (GWR)*, can be very useful in explaining the geographical disparities in health utilization.[12–13] Such approaches to oral health can also guide policy makers in the optimal resource allocations and the development of polices to eliminate disparities in dental services utilization. However, to date, very few studies have analyzed dental health (example: number of missing teeth) using geographical information techniques.[12–14] Two of these studies revealed disparities in the distribution of dentists in Appalachian Kentucky counties,[13] and oral health disparities measured by the percentage of adults with six or more permanent teeth removed.[12] However, none of these studies directly evaluated the relationship between dental workforce availability and dental services utilization.

Accordingly, the primary objective of the study was to describe variation in dental services utilization across Appalachian counties and analyze county-level variations in the relationships between dental workforce availability and dental services utilization. We hypothesized that the association between dental workforce availability and dental services utilization will vary across counties, after controlling for county-level differences in sex, age, race, and income.

Method

We conducted an ecological study at the county level in the Appalachian region to understand the geographical disparities of dental workforce availability and dental services utilization.

For this study, we linked the 2010 Behavioral Risk Factor Surveillance System (BRFSS)[15] with the Area Health Resources File (AHRF) data.[16] The BRFSS is a national health-related survey that collects data of health-related risk behaviors, chronic health conditions, and use of preventive services among US residents through standardized and random-digit–dialed telephone surveys of landline telephones and cellular telephones interviews. The BRFSS questionnaires composed core questions, optional modules, and state-specific questions. Data were weighted for the unequal probability of selection, differential nonresponse, and possible deficiencies in the sampling frame.[15] The AHRF provided county level data not limited to health issues from over 50 sources, including the American Dental Association (ADA), American Medical Association (AMA), and the U.S. Census Bureau.[16]

The BRFSS sample was restricted to adults over 18 years of age who were residents of the Appalachian counties and had no missing data on dental services utilization, and who had completed interviews in 2010 (unweighted N = 30,564). We excluded women who were pregnant (unweighted N = 1,877), because many pregnant women might not seek dental care due to radiation exposure and fetal safety. Thus, the final sample size consisted of 30,423 adults living in 364 Appalachian counties. We identified the Appalachian counties based on the definition from the Appalachian Regional Commission (ARC) and the Federal Information Processing Standards (FIPS) codes.

The dependent variable was the county-level percent of dental visits within the previous year. To derive this variable, we used patient-level information from the BRFSS. In the BRFSS, respondents were asked “How long has it been since you last visited a dentist or a dental clinic for any reason? Include visits to dental specialists, such as orthodontists.” The options for the responses were “within the past year”; “within the past 2 years”; “within the past 5 years”; “5 or more years ago”; “never”; and “refused”. We derived the weighted percent of individuals who had used dental services within the previous year for each county.

The key independent variables were the county-level active dentist-to-population ratio and the licensed dental hygienists-to-population ratio. We derived these variables from the AHRF. Since one dentist per 2,000 (1/2,000) residents is considered as an ideal dentist-to-population ratio,[17, 18] we converted the county-level active dentist-to-population ratio to the number of dentists per 2,000 residents in the county. Considering state policy differences for dental hygienists and a lack of consensus, we followed the same procedure as the dentist-to-population ratio to derive the licensed dental hygienists-to-population ratio. Hereafter, we refer to the dentists per 2,000 residents and dental hygienists per 2,000 residents as “concentration of dentists, or dental hygienists”.

Other independent variables consisted of the county-level percent adults over 40 years of age, percent of households with an annual income less than $15,000, the percent female, and percent White. We extracted these variables from the patient-level information in the BRFSS and aggregated them to the county-level. We calculated the physician-to-population ratio by dividing the number of physicians by the number of residents in the county. We extracted from the AHRF for the number of physicians and the number of residents in counties. Aggregated county-level data from the BRFSS and information from the AHRF was linked using the county FIPS codes.

We used multivariable ordinary least squares regression (OLS) to evaluate the association between dental workforce availability and dental services utilization. In these regressions, a positive co-efficient of the dental workforce availability will indicate that a higher concentration of dentists or dental hygienists is related to higher rates of the utilization of dental services.

We mapped the county-level dental workforce availability and county-level percent dental services utilization using ArcGIS 10.3. We used a natural break classification scheme to group county-level percent dental care visits within the last year into five categories, which minimized the deviation within the categories, and maximized the deviation between them. The concentration of both dentists and dental hygienists was grouped into two categories using the cut-off of 1.

We used global Moran's *I* and bivariate LISA (biLISA) to estimate spatial autocorrelations. The global Moran's *I* is an indicator of spatial association, with range between −1 (perfect dispersion) and +1 (perfect correlation). A value of zero for Moran's *I* indicates no spatial autocorrelation. However, Moran's *I* only measures the global spatial autocorrelation. Thus, we used biLISA to identify spatial patterns, which included low-low cluster, high-high cluster, high-low outlier, and low-high outlier. For example, the high-high spatial clustering indicates that a county with higher than average value is surrounded by neighboring counties with higher than average values for another variable. The null hypothesis in biLISA represents no spatial autocorrelation between the two variables (in our case dental workforce availability and dental services utilization), or the relationship between the two variables is random. The alternative hypothesis indicates that the relationship is not random (with spatial clustering or dispersion). A spatial weights matrix was applied to study the association among locations for both Moran's *I* and local LISA. We used queen contiguity weights matrix, which defined a county's neighbors as those that shared a border or vertex/corner. This weights matrix described all the closest neighboring counties for each location.[19] We calculated the LISA statistic for the significant level < 0.05 ($p < .05$) for each cluster and county. We used choropleth maps to display the patterns of the associations between dental workforce availability and dental services utilization.

We used GWR to display spatially varying relationships of dental workforce availability with dental services utilization. GWR is a local spatial statistical technique that examines the regression parameter varying across the study region.[20] As opposed to OLS, GWR typically generates multiple regression equations based on the centered county. Counties were re-centered to produce locally specific GWR parameters. Each GWR equation is expressed as

$$Y_i = \beta_{0*}\ (\mu_i, \nu_i) + \beta_{1*}\ (\mu_i, \nu_i)\ x_{i1} + \beta_{2*}\ (\mu_i, \nu_i)\ x_{i2} + \ldots\ \beta_{k\ *}\ (\mu_i, \nu_i)\ x_{ik} + \varepsilon_i$$

(μ_i, ν_i) is the location of the county. According to Tobler's first law of geography, "everything is related to everything else, but near things are more related than distant things."[21] Therefore, information in counties nearby is more important, than that for those farther away. Thus, weights were assigned to each county, based on the distance decay function. Distance decay function, modified by a bandwidth, was centered on county i, and decreased with the distance from i of the nearest N neighboring counties. Optimal N neighboring counties were determined by a variable bandwidth or an adaptive kernel. The optimal adaptive kernel size was determined through an iterative statistical optimization process that minimizes the Akaike Information Criterion (AIC), which uses both goodness-of-fit and degrees of freedom into consideration.[22] For each centered county separate t-statistics were calculated. These values were then mapped to visualize the spatial distribution on the county level. A Monte Carlo approach was also used, to test for spatial variability.[22]

SAS 9.3 (SAS Institute, Cary, NC), GWR 4.0 (Nakaya et al., 2009)[23], GeoDa 1.6.7 (GeoDa Center, Tempe, Arizona)[19], and ArcGIS 10.3 (ESRI, Redlands, CA) were used for the analyses in this study.

Results

County-level percent dental services utilization within the previous year for 364 Appalachian counties was based on 30,423 respondents to the BRFSS, representing 18,456,952 residents in Appalachia. The average county-level percent dental services utilization was 60.3% and ranged from as low as 16.5% to as high as 91.0% with the inter-quartile range (IQR) 53.0–68.7%. The average dentist-to-population (2,000) ratio was 0.60 with IQR 0.35–0.81, and the average dental hygienist-to-population (2,000) ratio was 0.95 with IQR 0.61–1.28 (the data was not presented in tabular form).

Table 1 presents the correlations of all the explanatory variables with the county-level percent dental services utilization. Dentist-to-population (2,000) ratio, dental hygienist-to-population (2,000) ratio, and the county-level percent adults over 40 years of age, were positively associated ($p < 0.01$) with the percent of dental services utilization in the previous year, while the percent of households with an annual income less than $15,000 was negatively associated ($p < 0.01$) with the dental services utilization. Table 1 also summarizes results from the multivariable OLS regression on the county-level percent dental services utilization. These results were consistent with the correlations. For example, dentist-to-population (2,000) ratio was significantly associated with county level percent dental services utilization, after controlling for other explanatory variables. Thus, for one unit increase in the ratio, we can expect to see a 6.2 percentage point of increase in the percent of dental services utilization ($p < .01$).

Figure 1 displays the choropleth maps for the county-level percent of dental services utilization and the dentist (dental hygienist)-to-population (2,000) ratio. Missing values of the counties were filled with no color (or white color) in all maps of this study. The majority (85.4%, 311/364) of the Appalachian counties did not have the ideal ratio of one dentist per 2,000 residents. Most counties in northern Alabama and Georgia had a high dental-hygienist-to-population ratio and counties in West Virginia, Kentucky, and Mississippi had a low dental-hygienist-to-population ratio.

Based on biLISA, we found that the values of Moran's *I* for both dentist-to-population ratio (Moran's I=0.04) and dental hygienist-to-population ratio (Moran's I=0.11) were larger than 0. We found four distinct spatial patterns of the association between dental workforce availability and dental services utilization. These were: (1) low-low cluster (low dental workforce availability & low dental services utilization or “cold spot”); (2) high-high cluster (high dental workforce availability & high dental services utilization or “hot spot”); (3) low-high outlier (low dental workforce availability & high dental services utilization); and (4) high-low outlier (high dental workforce availability & low dental services utilization). We found low-low clusters in the southern region of West Virginia, eastern Tennessee, and northeast Mississippi. A low-low cluster suggests that counties with lower than average concentrations of dentists (or dental hygienists) were surrounded by counties with lower than average dental services utilization (Figure 2).

We summarize the outcome of univariate GWR and multivariable GWR in Figure 3. There was a significant spatial variability only for the dental hygienist-to-population ratio based on “DIFF of criteria” provided by GWR 4.0. We distinguished between positive and negative clusters using the cut-off point ±1.96 for t-statistics and the associated 95% confidence interval. In 21% (78/364) of the counties, a strong association was found between the dentist-to-population ratio and the dental services utilization in the univariate GWR (Figure 3.1). However, this was only 8.5% (31/364) in the multivariable GWR (Figure 3.5). In terms of the concentration of the dental hygienists, positive associations with dental services utilization were found for 13.5% (49/364) of the Appalachian counties in both univariate and multivariable GWR (Figure 3.2, Figure 3.7, Table 2).

Discussion

This is the first study to conduct an ecological examination of the relationship between dental workforce availability and dental services utilization using the linked BRFSS and AHRF databases. We found that dental services utilization was low in southern areas of West Virginia and Ohio, counties in eastern Kentucky and Tennessee, and northeastern Mississippi. Considering the poor oral health in Appalachia reported by the previous studies,[1, 3] our findings suggest future interventions to improve the dental services utilization in these regions. Standard regression analyses revealed a global association between dental workforce availability and dental services utilization after controlling for sex, age, race composition, and household income. However, GWR suggested variations in this relationship across different counties. Therefore, our study findings suggest the need for spatial analysis of supply and demand relationships.

We found geographical variations in dentists-to-population ratio and dental hygienists-to-population ratio. Some of these variations may be due to state policy differences. For example, in West Virginia, a dentist cannot have more than three dental hygienists and such policy may not be in place in other states[24]. Furthermore, dental practice locations may be based on market availability, socio-economic status of the area, and expected profitability of the practice.[25, 26] Most of the Appalachian counties did not have one dentist per 2,000 residents. This may lead to poor access to dental care and consequent poor oral health outcomes. This finding has implications for dental care demand. In 2010, the Patient Protection and Affordable Care Act commonly known as ACA[27] was passed to expand affordable high-quality health insurance coverage in the United States either through Medicaid[28]- a joint federal-state program that helps low-income individuals or through health insurance bought from the market place (i.e. health insurance exchanges).[29] Although the ACA did not mandate dental insurance coverage, it is estimated that 17.7 million adults may obtain some dental coverage because of Medicaid expansion or health insurance exchanges.[30] It is well established that the lack of dental insurance coverage reduces dental utilization and leads to poor oral health.[1, 31] Therefore, expanded insurance coverage may increase dental services utilization (i.e. demand) also known as a moral hazard of dental insurance. Thus, by examining only the concentration of dentists in counties, there may be calls for enhancing the supply and training of dental work force through public programs such as the Title VII Training in General, Pediatric, and Public Health Dentistry program.[32]

However, our findings on the relationship between dental workforce availability and dental services utilization do not support such implications. Our study findings from the spatial analyses revealed that a very small number of counties (31/364) had positive associations between the dental workforce and the utilization of dental services. Furthermore, in the standard OLS regression model, when the average per capita income of the county was adjusted, the significant and positive relationship between dental workforce availability and dental services utilization disappeared. Taken together, these findings suggest that dental workforce availability may not be the most important predictor of dental services utilizations in Appalachia. Research, policy, and planning efforts need to focus on economic development and factors other than dental workforce availability in improving the dental services utilization.

With regard to the dentist-to-population ratio, bivariate LISA revealed low-high clusters in the southeastern Appalachian region (north of Georgia). The low-high clusters suggest that some of these counties have relatively higher dental utilization despite a low concentration of dentists. Although we controlled for spatial relationships, the presence of low-high clusters may suggest that the residents in these counties may be more likely to obtain dental services from the neighboring counties. Future research needs to explore the reasons for such low-high clusters.

We also found high-low clusters in the southern parts of West Virginia, where they had more than one dentist per 2,000 residents. This finding suggests that despite the availability of the dental workforce, in these regions the dental services utilization remained low. These findings, again, highlight the need for further investigation of factors (other than dental workforce availability, e.g. dental health insurance, person's income status, and education). This may affect dental services utilization.

The current study has advantages and limitations. We used a nationally representative survey, ideally suited for examining oral health care. We linked the BRFSS database with the AHRF and this linkage enabled us to conduct an ecological study of the relationship between dental workforce availability and dental services utilization. We applied both standard and spatial analyses, and our findings revealed the need for spatial analysis of the supply and demand of dental care. However, some limitations of the study need to be noted. Since the BRFSS did not interview residents in very small counties, our findings are applicable only to counties with available data. The bandwidth, borders, the weights, and explanatory variables included in the model can affect the findings from the spatial analyses. We did not have information on important variables such as dental insurance coverage, which may have affected the relationship between dental workforce availability and dental services utilization. It must be noted that our study is an exploratory study and future research needs to explore the travel patterns for dental utilization and use this information in any spatial analysis. In addition, as our models are based on data aggregated to the county-level, we acknowledge that there may be an ecological fallacy and the associations between variables and dental services utilization may not be reflective of the associations at the individual-level within the county.

In conclusion, this study documented the geographical differences in both dental workforce availability and dental services utilization in Appalachian counties. Although, standard regression analyses highlighted a positive relationship between dental workforce availability and dental services utilization, spatial analyses revealed a positive relationship only in a small number of counties (in 333 /364 counties, there was no significant relationship between dentist-to-population ratio and the utilization of dental services). Our results suggest that future research, program and policy efforts to improve dental services utilization in Appalachia need to examine factors other than dental workforce availability.

Acknowledgments

Funding

Research reported in this publication was supported by the National Institute Of General Medical Sciences of the National Institutes of Health under Award Number U54GM104942. The content is solely the responsibility of the author and does not necessarily represent the official views of the National Institutes of Health. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

1. Krause, DD., May, WL., Lane, N., Cossman, J., Konrad, T. An analysis of oral health disparities and access to services in the Appalachian region. Appalachian Regional Commission; Washington, DC: 2011.
2. Appalachian Regional Commission. [Accessed June 23,2016] The Appalachian Region. 2016. Available at: http://www.arc.gov/appalachian_region/TheAppalachianRegion.asp
3. Gorsuch MM, Sanders SG, Wu B. Tooth loss in Appalachia and the Mississippi Delta relative to other regions in the United States, 1999–2010. Am J Public Health. 2014; 104:e85–e91.

4. Russell SL, Gordon S, Lukacs JR, Kaste LM. Sex/gender differences in tooth loss and edentulism: historical perspectives, biological factors, and sociologic reasons. Dent Clin North Am. 2013; 57:317–337. [PubMed: 23570808]
5. Wennström A, Ahlqwist M, Stenman U, Björkelund C, Hakeberg M. Trends in tooth loss in relation to socio-economic status among Swedish women, aged 38 and 50 years: repeated cross-sectional surveys 1968–2004. BMC Oral Health. 2013; 13:1. [PubMed: 23280327]
6. American Dental Association. [Accessed September 23,2016] American Dental Association Statement on Regular Dental Visits. 2013. Available at: http://www.ada.org/en/press-room/news-releases/2013-archive/june/american-dental-association-statement-on-regular-dental-visits
7. Richards W, Ameen J. The impact of attendance patterns on oral health in a general dental practice. British dental journal. 2002; 193:697–702. [PubMed: 12529726]
8. Ford, TR. The southern Appalachian region: A survey. University Press of Kentucky; 2015.
9. Vargas CM, Yellowitz JA, Hayes KL. Oral health status of older rural adults in the United States. J Am Dent Assoc. 2003; 134:479–486. [PubMed: 12733783]
10. Allison RA, Manski RJ. The supply of dentists and access to care in rural Kansas. The Journal of Rural Health. 2007; 23:198–206. [PubMed: 17565519]
11. West Virginia Department of Health and Human Resources. West Virginia Oral Health Plan 2010 – 2015. 2010. Available at: https://www.wvdhhr.org/mcfh/ICAH/WV_Oral_Health_Plan_2010.pdf
12. Saman DM, Johnson AO, Arevalo O, Odoi A. Geospatially illustrating regional-based oral health disparities in Kentucky. Public Health Rep. 2011:612–618. [PubMed: 21800757]
13. Saman DM, Arevalo O, Johnson AO. The dental workforce in Kentucky: Current status and future needs. J Public Health Dent. 2010; 70:188–196. [PubMed: 20345738]
14. Horner MW, Mascarenhas AK. Analyzing location based accessibility to dental services: an Ohio case study. Journal of Public Health Dentistry. 2007; 67:113–118. [PubMed: 17557683]
15. Behavioral Risk Factor Surveillance System. [Accessed June/23, 2016] BRFSS 2010 Survey Data and Documentation. 2016. Available at: http://www.cdc.gov/brfss/annual_data/annual_2010.htm
16. Area Health Resources Files. [Accessed June/23, 2016] AHRF Database. 2016. Available at: http://ahrf.hrsa.gov/
17. Brown, T. [Accessed June 24, 2016] Chart count-how many patients do you have?. Available at: http://roicorp.com/981/
18. National Maternal and Child Oral Health Resource Center. [Accessed June 24, 2016] What indicators can be used to analyze efficiency?. 2011. Available at: http://dentalclinicmanual.com/chapt6/3_6.html
19. Anselin L, Syabri I, Kho Y. GeoDa: an introduction to spatial data analysis. Geogr Anal. 2006; 38:5–22.
20. Gilbert A, Chakraborty J. Using geographically weighted regression for environmental justice analysis: Cumulative cancer risks from air toxics in Florida. Soc Sci Res. 2011; 40:273–286.
21. Tobler WR. A computer movie simulating urban growth in the Detroit region. Economic geography. 1970; 46:234–240.
22. Fotheringham, AS., Brunsdon, C., Charlton, M. Geographically weighted regression: the analysis of spatially varying relationships. John Wiley & Sons; 2003.
23. Nakaya, T., Fotheringham, A., Charlton, M., Brunsdon, C. Semiparametric geographically weighted generalised linear modelling in GWR 4.0. 2009.
24. West Virginia Board of Dentistry. [Accessed Feb 28, 2016] Expended Duties. 2016. Available at: http://www.wvdentalboard.org/Laws/5CSR13.pdf
25. Solomon ES. Demographic characteristics of general dental practice sites. General dentistry. 2006; 55:552–8.
26. McKernan SC, Kuthy RA, Kavand G. General dentist characteristics associated with rural practice location. The Journal of Rural Health. 2013; 29:s89–95. [PubMed: 23944285]
27. Act AC. Affordable Care Act. 2011.
28. U.S. Centers for Medicare & Medicaid Services. [Accessed September 23, 2016] Medicaid expansion & what it means for you. 2016. Available at https://www.healthcare.gov/medicaid-chip/medicaid-expansion-and-you/

29. U.S. Centers for Medicare & Medicaid Services. [Accessed September 23, 2016] A quick guide to the Health Insurance Marketplace. 2016. Available at: https://www.healthcare.gov/quick-guide/
30. American Dental Association. [Accessed June 23, 2016] Affordable Care Act, dental benefits examined. 2013. Available at: http://www.ada.org/en/publications/ada-news/2013-archive/august/affordable-care-act-dental-benefits-examined
31. Wall TP, Vujicic M, Nasseh K. Recent trends in the utilization of dental care in the United States. Journal of dental education. 2012; 76:1020–1027. [PubMed: 22855587]
32. Morrissey, T. The Affordable Care Act's public health workforce provisions: Opportunities and challenges. American Public Health Association; 2011.

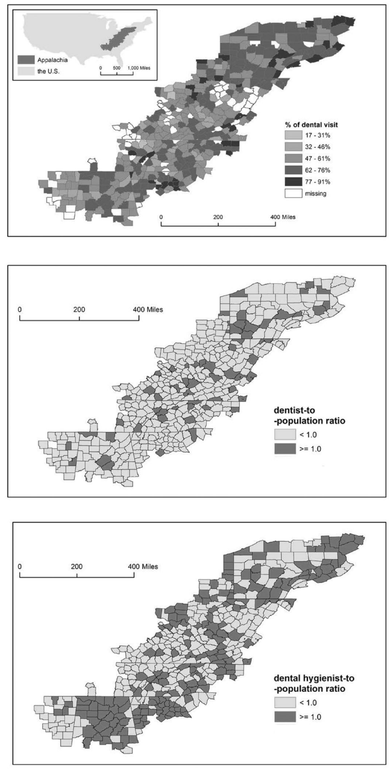

Figure 1.

Choropleth Map of the Dental Services Utilization, Dentists, and Dental Hygienists by County

Footnote: The dentist-to- population ratio above "1" indicates that the dental workforce availability of the county is above the ideal ratio."

Author Manuscript
Author Manuscript
Author Manuscript

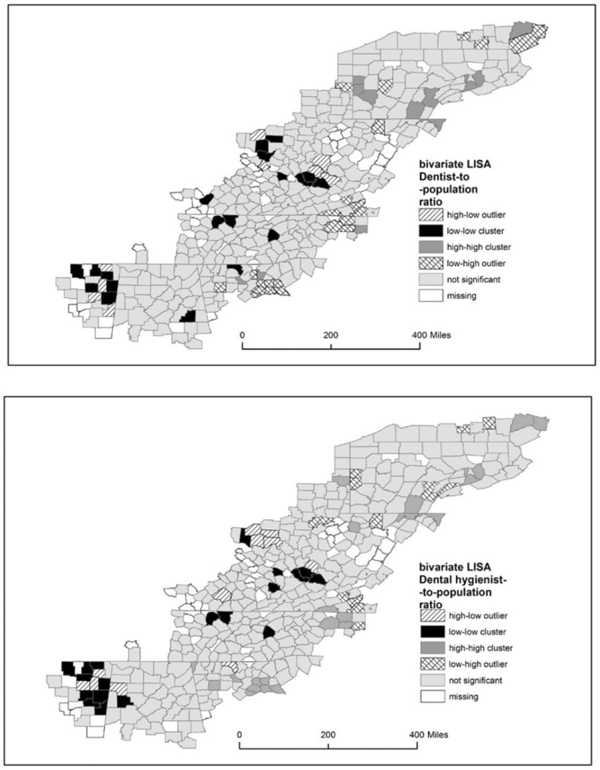

Figure 2.
BiLISA of Association between Dental Workforce and Dental Services Utilization

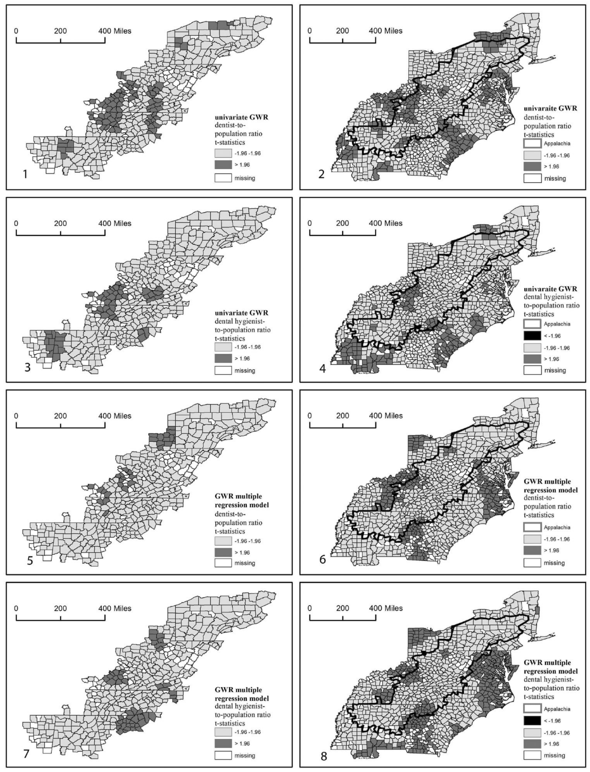

Figure 3.

T-statistics of GWR Models

Table 1

Correlation of independent variables with county-level dental service utilization*

			Correlation between Dental Service Utilization		OLS† on Dental Services Utilization		
Variables	Mean	SD‡	Correlation	P-value	Beta	SE§	P-value
Dentist to population (2,000) ratio							
Intercept					53.73	6.45	<0.01
Dentist to population ratio	0.59	0.33	0.24	<0.01	6.20	2.10	<0.01
Physician to population ratio	0.001	0.002	0.18	<0.01	384.07	360.91	0.29
County-level percent aged over 40 (%)	68.05	12.27	0.17	<0.01	0.16	0.05	<0.01
County-level percent female (%)	52.06	9.86	0.35	0.49	−0.30	0.06	0.55
County-level percent annual households' income <$15,000 (%)	13.63	8.70	−0.29	<0.01	−0.04	0.07	<0.01
County-level percent white (%)	89.50	12.08	0.02	0.55	−0.03	0.05	0.56
Dental hygienist to population (2,000) ratio							
Intercept					54.23	6.47	<.01
Dental hygienist to population ratio	0.97	0.52	0.22	<.01	3.28	1.28	0.01
Physician to population ratio	0.001	0.002	0.18	<.01	841.30	318.54	<.01
County-level percent aged over 40 (%)	68.05	12.27	0.17	<.01	0.14	0.05	<.01
County-level percent female (%)	52.06	9.86	0.35	0.58	−0.04	0.06	0.54
County-level percent annual households' income < $15,000 (%)	13.63	8.70	−0.29	<.01	−0.30	0.07	<.01
County-level percent white (%)	89.50	12.08	0.02	0.80	−0.02	0.05	0.69

*Based on 18,456,952 weighted residents of 364 Appalachian counties, beta and Standard errors are from ordinary least squares regression on county-level percent dental services utilization in the past year.

†OLS: Ordinary Least Squares;

‡SD: Stand Deviation;

§SE: standard error;

Table 2

GWR Coefficients and t-statistics. Appalachia, 2010

	GWR coefficient			t-statistics of percentage of county by significance (95% level)		
	Min	**Median**	**Max**	**< −1.96**	**−1.96 to 1.96**	**> 1.96**
Dentist to population (2,000) ratio						
Univariate GWR						
Dentist to population ratio	−4.93	2.93	8.38	0.0%	78.6%	21.4%
Multiple GWR						
Dentist to population ratio	−6.17	2.56	10.77	0.0%	91.5%	8.5%
Physician to population ratio	−13.80	1.00	14.24	0.6%	98.9%	0.6%
County-level percent aged over 40 (%)	−5.40	0.01	7.67	1.4%	97.0%	1.5%
County-level percent female (%)	−3.63	0.43	6.31	0.0%	91.5%	8.5%
County-level percent households' annual income < $15,000 (%)	−9.23	−1.35	4.04	6.3%	93.7%	0.0%
County-level percent white (%)	−11.16	0.03	15.05	5.8%	90.1%	4.1%
Dental-hygienist to population (2,000) ratio						
Univariate GWR						
Dental-hygienist to population ratio	−3.92	2.19	10.81	0.0%	86.5%	13.5%
Multiple GWR						
Dental-hygienist to population ratio	−3.53	1.95	11.19	0.0%	86.5%	13.5%
Physician to population ratio	−5.20	2.64	21.11	0.0%	86.8%	13.2%
County-level percent aged over 40 (%)	−4.81	0.09	8.17	0.0%	98.1%	1.9%
County-level percent female (%)	−3.95	0.27	6.62	0.3%	91.8%	8.0%
County-level percent households' annual income <$15,000 (%)	−8.81	−1.34	4.11	9.3%	90.7%	0.0%
County-level percent white (%)	−10.89	−0.49	14.56	5.2%	88.2%	6.6%

Note: <−1.96 indicated negative significant; −1.96–1.96 indicated no significant; >1.96 indicated positive significant.